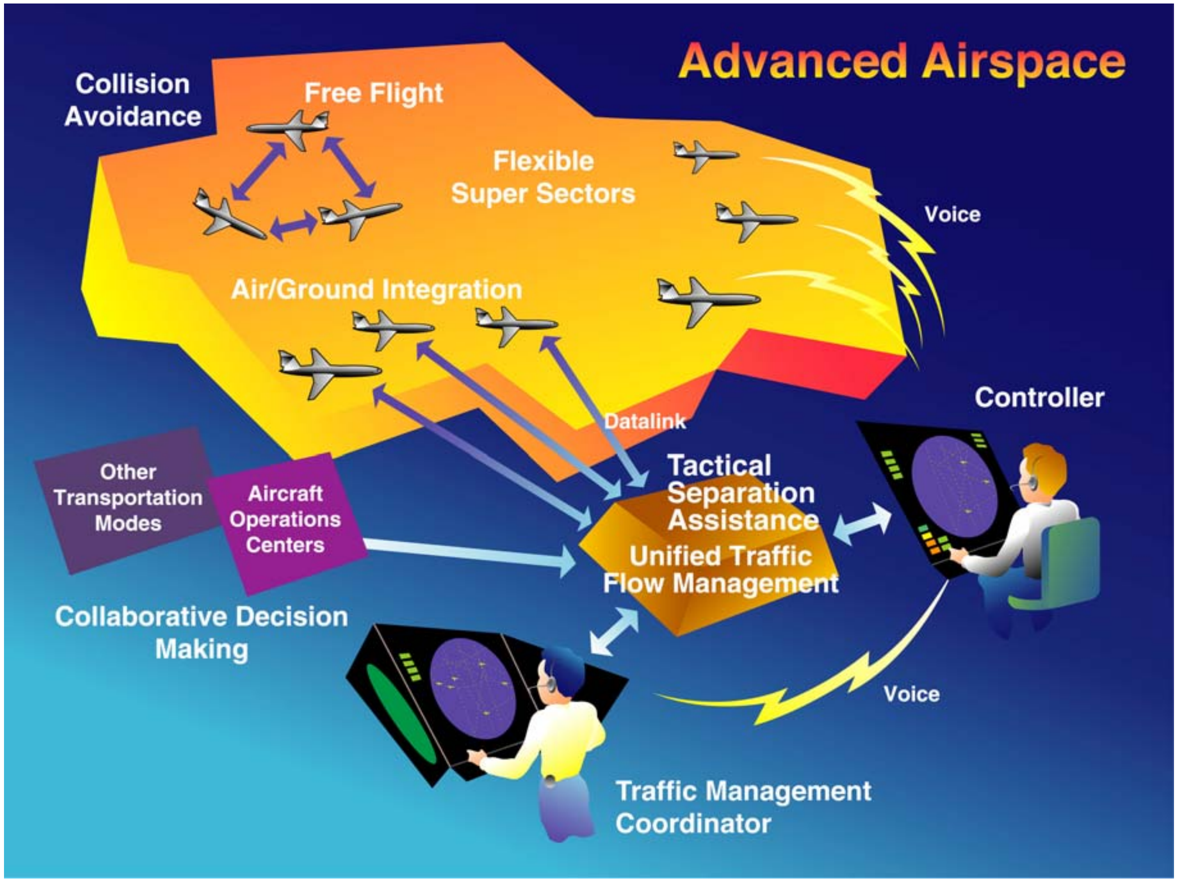
Advanced Airspace Concept



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Presented at VAMS-TIM4, Feb. 10, 2004

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Overview

- Concept of operations
- System architecture
- Operational procedures
- Initial AAC operations
- AAC trajectory services
- TSAFE conflict detection and performance
- Safety analysis

Concept of Operations

Pilots choose trajectories and downlink them to AAC

AAC ensures that pilot-requested trajectories meet traffic control constraints; then uplinks approved trajectories

AAC checks continuously for conflicts and uplinks trajectories to aircraft when necessary to ensure separation

Separation assurance becomes combined responsibility of AAC and aircraft after controller has handed off aircraft to AAC

Controller can resume manual control of an aircraft at his discretion or upon pilot request

AAC sectors consist of several conventional sectors combined into super-sectors

Current vs. Future Ground Interactions

Current System

Controllers issue **clearances** manually

Aircraft in sector

1.
2.
…
7.
…
15.

Channel capacity: 6 **clearances** per minute delivered serially in priority order.

Non-safety related services unavailable during periods of high workload

AAC

A/C request and receive trajectories from automated ground system via data link

Ground System

Aircraft in sector

1.
2.
…
7.
…
15.
…
27.
…
45.

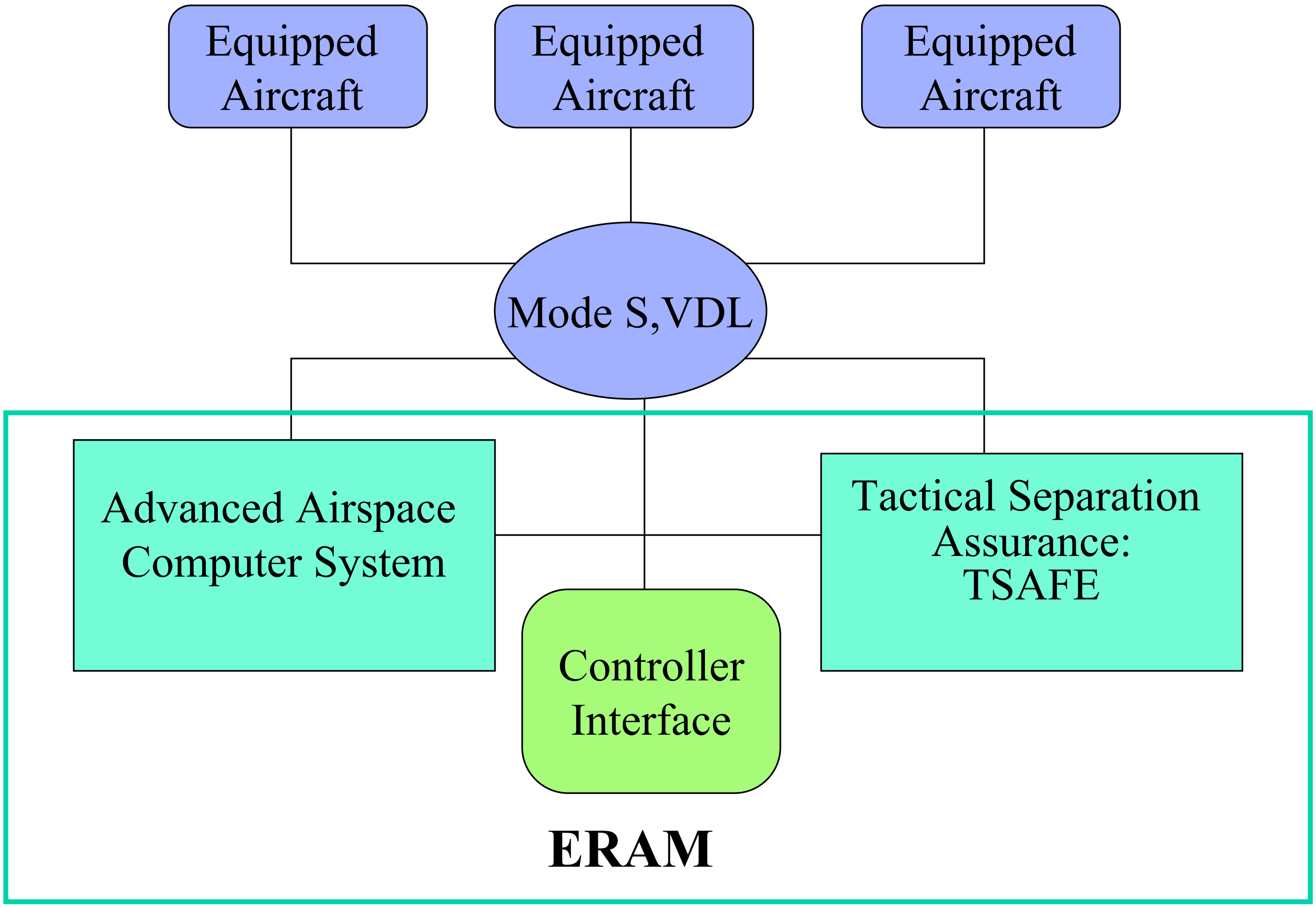
•Serves multiple aircraft concurrently, conflict free

•Uplinks trajectories when required for separation assurance

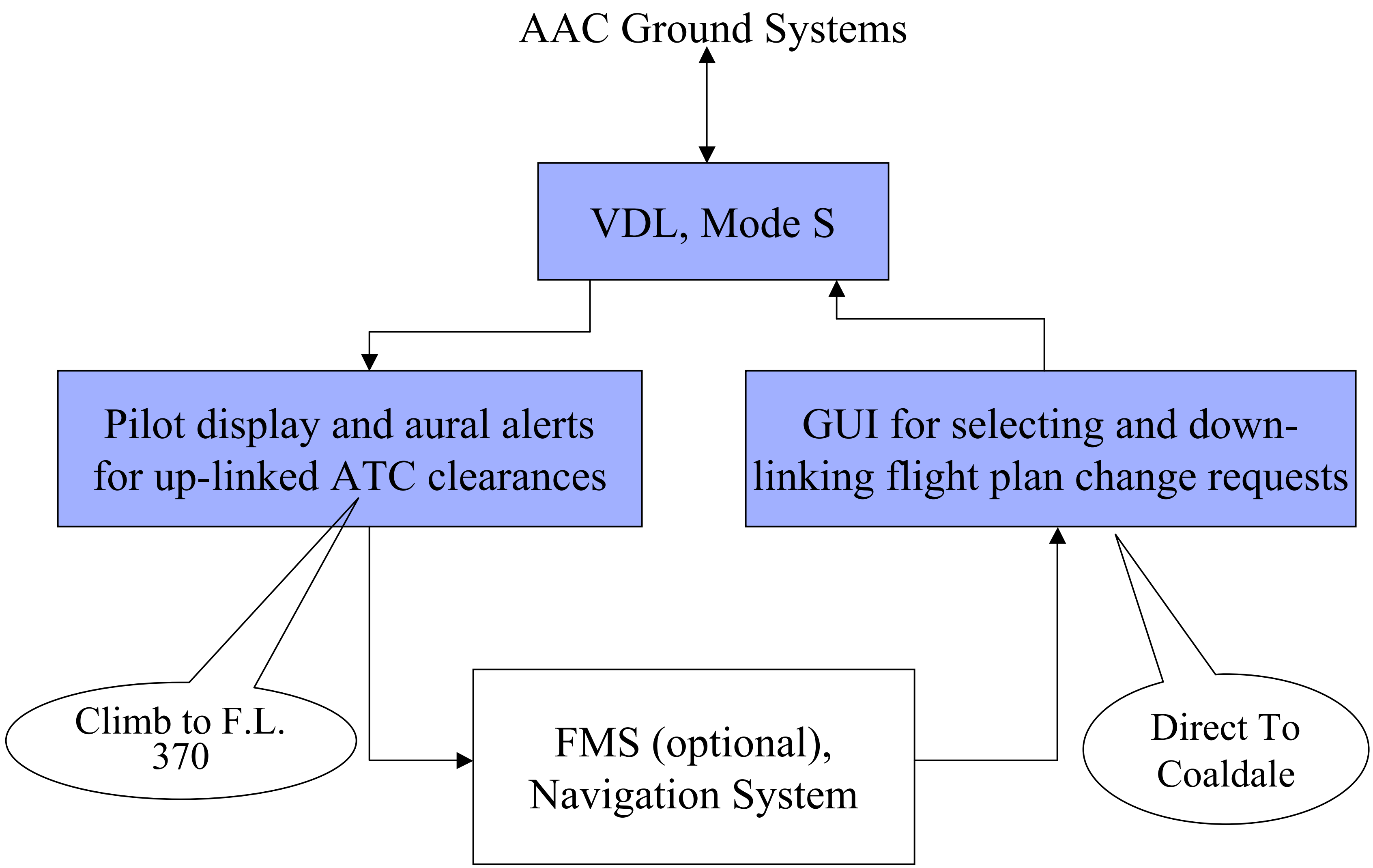
•**Channel capacity**: 60 **trajectories** per min. (estimated) per sector

•Controller handles any aircraft requiring special services (such as #27)

System Architecture

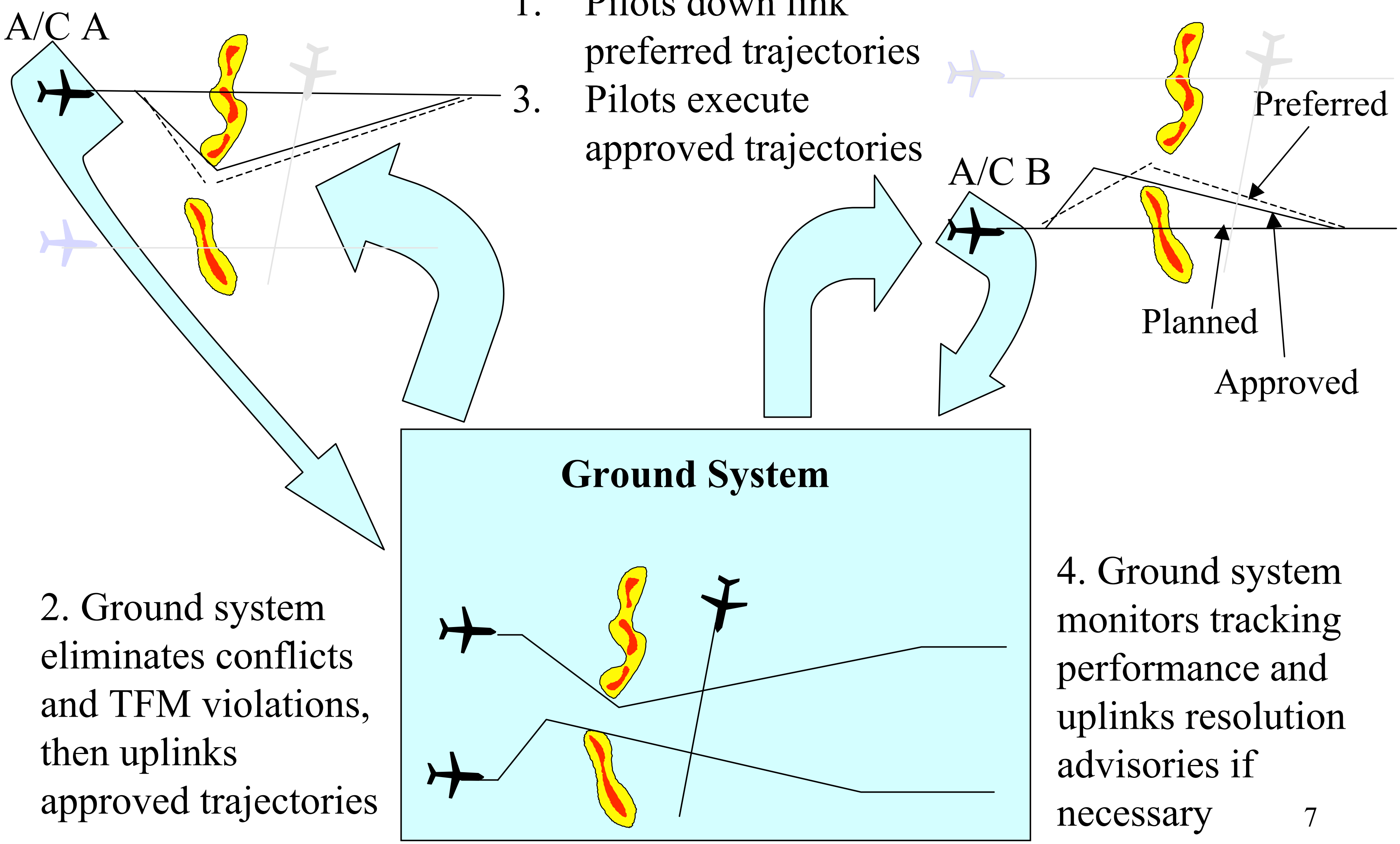


On Board Systems for Initial Build of AAC



AAC En Route Procedures

1. Pilots down link preferred trajectories
3. Pilots execute approved trajectories

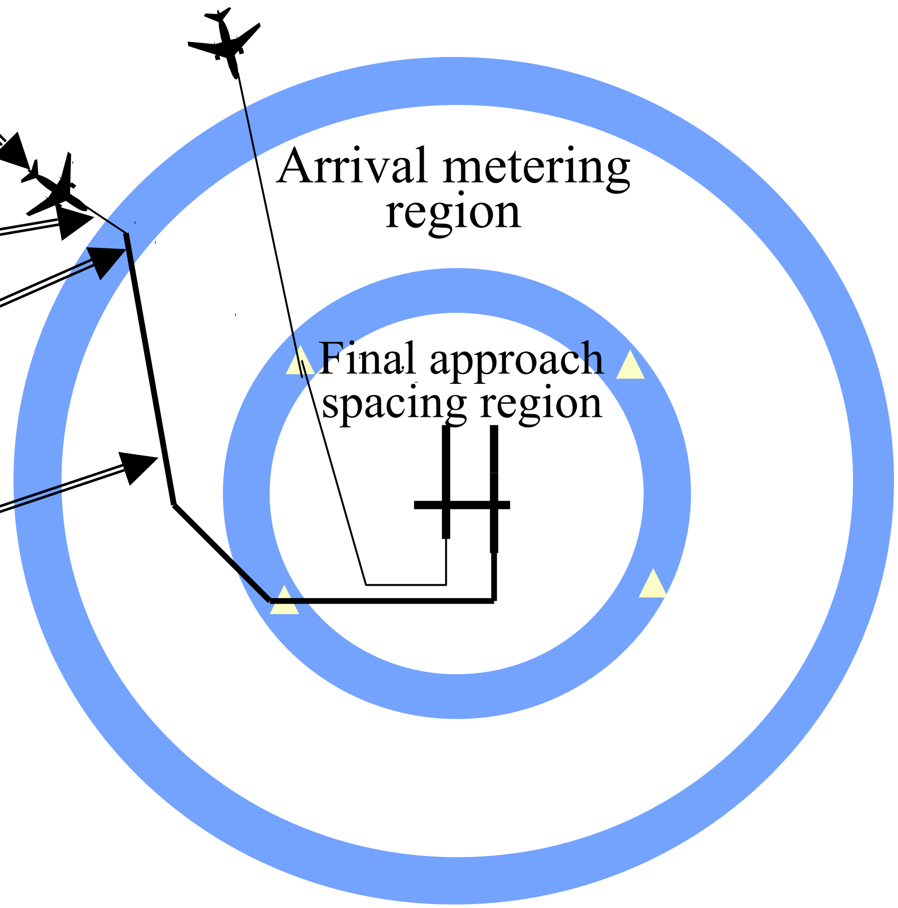


2. Ground system eliminates conflicts and TFM violations, then uplinks approved trajectories

4. Ground system monitors tracking performance and uplinks resolution advisories if necessary

AAC Arrival Procedures

1. Pilot downlinks preferred landing runway and the desired sequence order within its airline arrival bank
2. Ground System uplinks assigned arrival trajectory, landing runway, sequence order
3. Pilot loads trajectory into FMS and executes
4. Ground System uplinks revised trajectories when necessary to correct for deviations and to resolve conflicts



Pilot Interface Adopted from CPDLC

AAC has uplinked an altitude change clearance. Pilot must downlink an accept or reject message within a specified time period.

Pilot Interface (continued)

Pilot has accepted clearance (WILCO) and AAC has uplinked acknowledgment of acceptance.

Controller Interface (adopted from CPDLC)

Indicator for session in progress

Indicator for CPDLC equipped aircraft

Elements and Availability Dates for Initial AAC Build

Ground Systems

• ERAM	Initial deployment in 2008
• Automated trajectory services	Deployment feasible in 2012
• TSAFE	Deployment feasible in 2012
• CPDLC	Initial build operational at Miami Center
• DSR controller interface	Initial CPDLC functions in service
• VDL transmitters	Operational in Miami Center

On Board Systems

• VDL-2 radio • CPDLC cockpit display integrated with FMS (if equipped) • Current nav/com equipment standards for operation in class A airspace	Installations in progress; 75% of airline fleet expected to be equipped in 2010;

Procedures for Transitioning to Initial AAC Operations

- Unrestricted mix of equipped and unequipped aircraft permitted initially in AAC enabled airspace
- Controller decides if/when to "hand off" an equipped aircraft to AAC in his airspace and when to resume manual control
- AAC trajectory clearances are echoed to controller using appropriate data tag indicators and graphical markers on DSR
- Start time of AAC trajectory changes counts down before taking effect, giving controllers time to reject or revise
- Limited types of AAC trajectory clearances: for example, altitude amendments only or route amendments only
- Procedures will be selected to gain effective workload reduction subject to controller acceptance

Steps in AAC Operational Capabilities

Functions/ Performance	Initial	Mature
Data link message protocols	CPDLC message set	CPDLC with XML extensions
Trajectory specifications	Conventional flight plans and clearances	4D trajectories
Guidance and navigation requirements	Current standards and systems	FMS with 4D tracking mode and GPS
Equipage types in AAC controlled airspace	Mixed equipped and unequipped aircraft	Predominantly equipped aircraft
Separation standards	Current standards + RVSM	Reduced horizontal standards
AAC sector design	Moderately enlarged, similar to current design	3-5 conventional sectors combined into one
Capacity gains compared to current standards	0-30% increase, depending on A/C equipage mix	100-200% increase
Safety gains	50% reduction in operational error rate	90% reduction in operational error rate

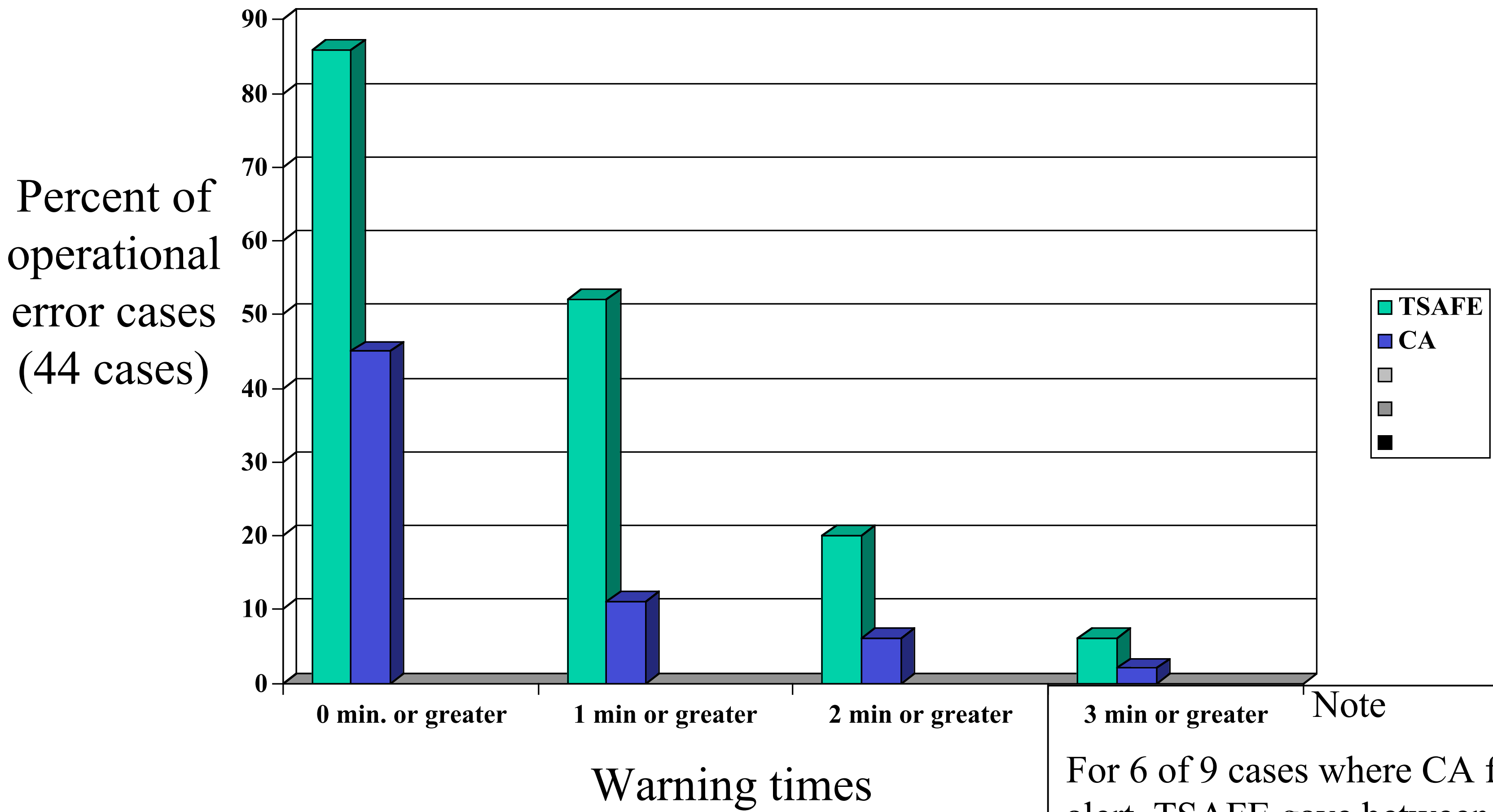
Tactical Separation Assured Flight Environment (TSAFE)

- Provides a safety net for certain types of faults or failures
  - TCAS equivalent for the ground system
  - Independently monitors separations and provides conflict resolutions
- Short detection horizon (~3 min.)
  - Dead reckoning (3D velocity vector) combined with near term flight plan intent is used for conflict detection
- Critical maneuver and no-transgression-zone alerts data-linked to aircraft
- Avoidance maneuvers to provide a short period of conflict-free flight (~3 min.)
  - Climb (or descend) to an assigned altitude level
  - Turn right (or left) to an assigned heading
  - AACS or controller responsible for generating strategic solution within ~3 minutes

COMMON CLASSES OF OPERATIONAL ERRORS
altitude transition involved in 42 of 44 cases

CLASS	**count**
Failure to project effect of altitude clearance	25
Altitude clearance readback error; ACID mixup	11
Direct clearance (route amendment)	2
Failure to protect holding pattern airspace	2

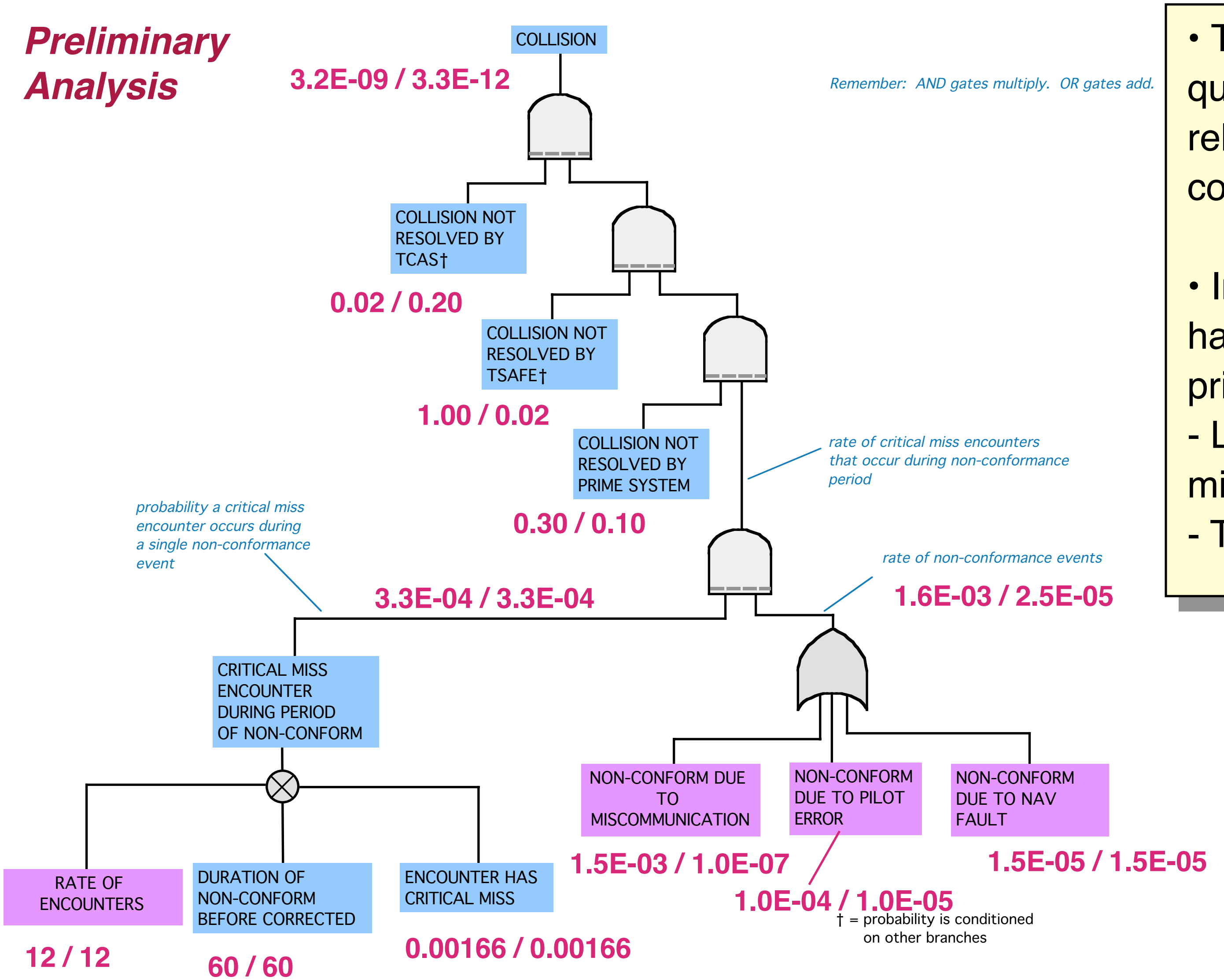
Comparison of Warning Times for TSAFE and Conflict Alert (preliminary results)



Note

For 6 of 9 cases where CA failed to alert, TSAFE gave between 30 sec and 3 min. warning time.

Conventional vs. AAC Collision Rate per Hour



- This is a preliminary quantitative analysis of relative safety in non-conformance events.
- In this example, AAC has advantage due primarily to:
  - Lower rate of miscommunication
  - TSAFE

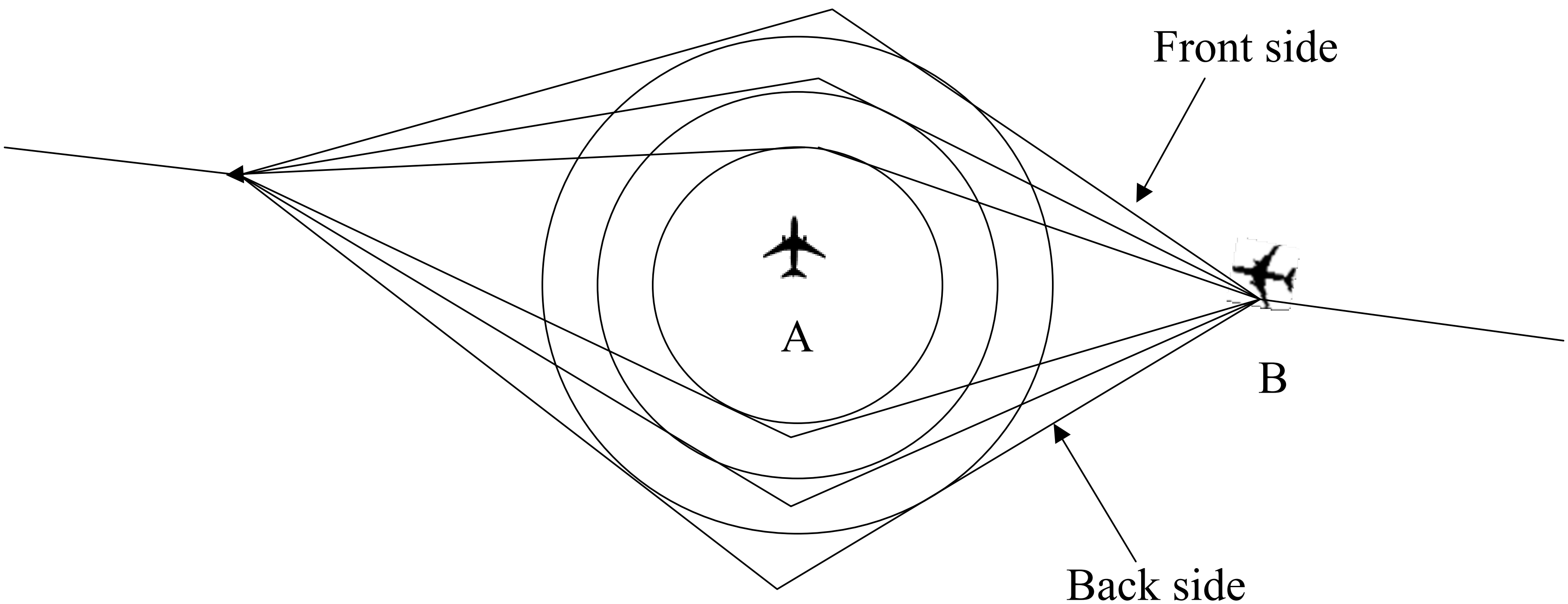
CONCLUDING REMARKS

- AAC has potential to increase capacity substantially by reducing controller workload associated with tactical separation assurance
- Ground-based system provides automated trajectory services and separation assurance to aircraft via datalink
- CPDLC, VDL and ERAM provide the essential infrastructure for supporting AAC operations
- AAC operations can be introduced in evolutionary steps, beginning in about 2012
  - In initial operations, equipped aircraft are assigned to AAC at discretion of controller
  - Trajectory transactions between AAC and equipped aircraft will be limited in scope initially
- TSAFE element of AAC has potential to reduce operational errors in current system

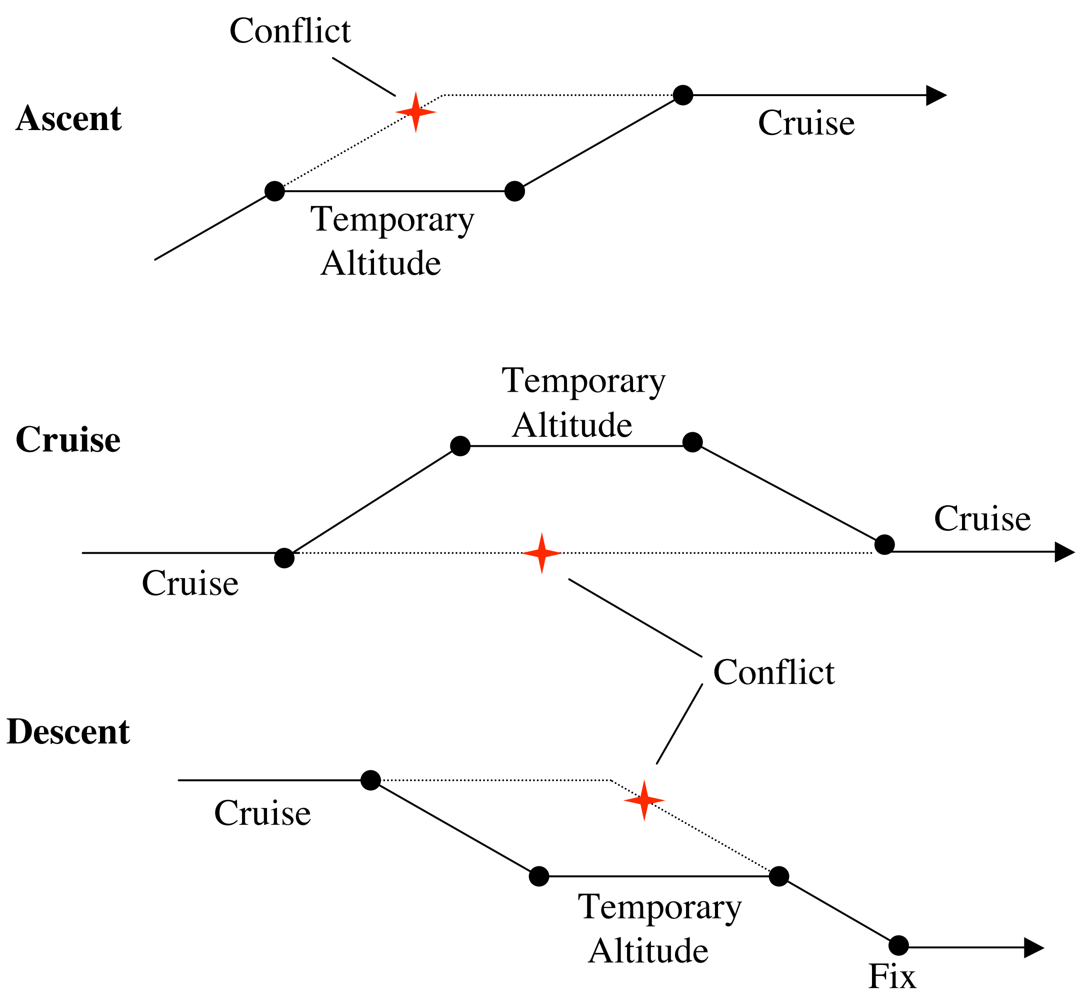
AAC Traffic Control Functions

- En Route Trajectory Services
  - Pilot initiated requests for trajectory changes
  - Ground System initiated trajectory changes
    - Conflict resolution and TFM constraint resolution
    - Weather diversions
    - Controller initiated trajectory changes
- Merging Streams Trajectory Control
  - Pilot requests for runway preference and landing sequence
  - Ground System Functions
    - Feeder gate sequencing and spacing
    - Final approach sequencing and spacing
    - Spacing control at merge points (en route or terminal area)

Family of Horizontal Resolutions
(in A/C A relative coordinates)



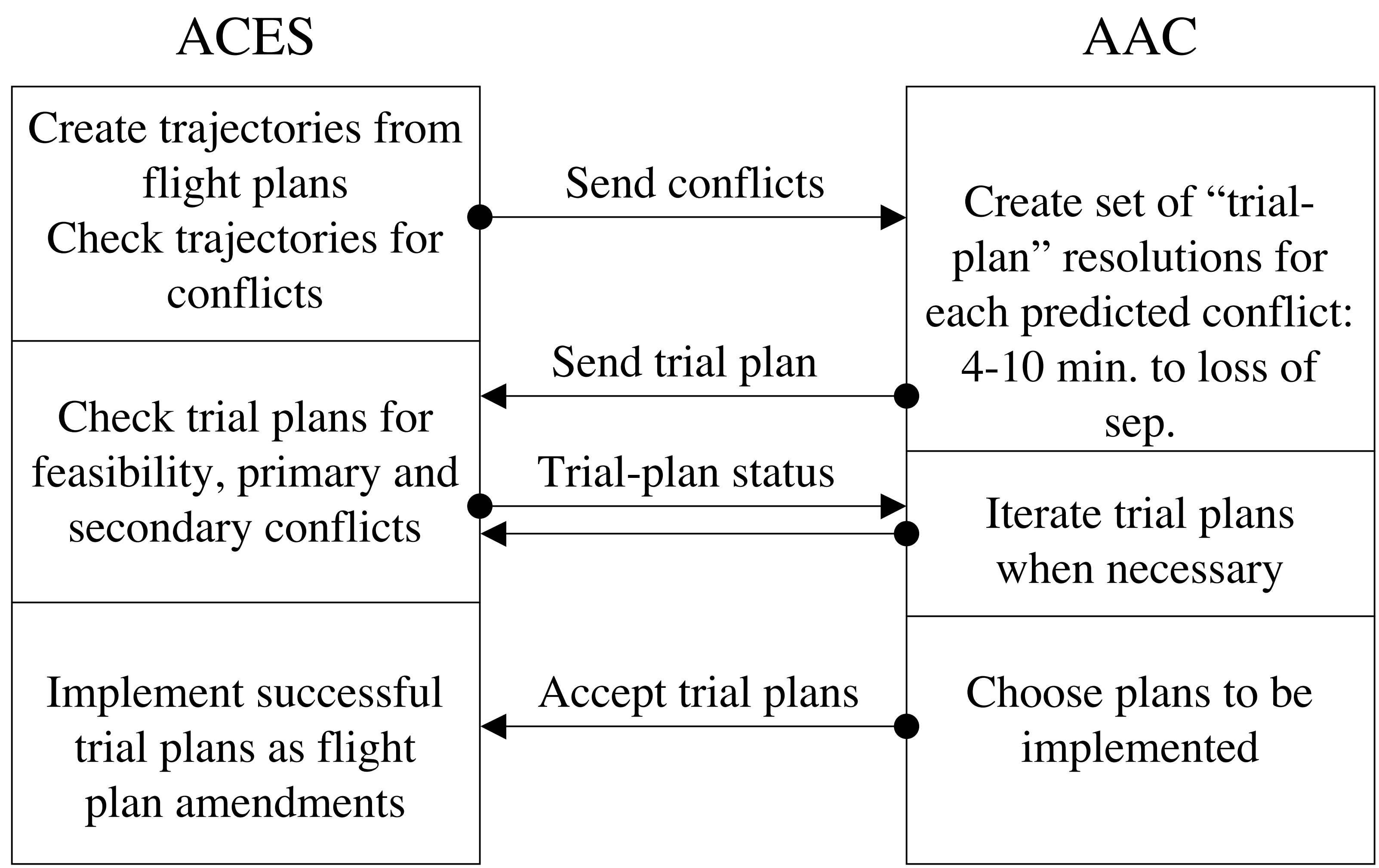
Vertical Resolution Types



On Going AAC Capacity Evaluation with ACES

- Initial altitude resolution logic has been implemented
  - Performance analysis in progress
- Causes for trial-plan failure in ACES simulation:
  - Secondary conflicts along trial-plan trajectory
  - Violation of aerodynamic envelope
  - **Original flight plan must be recaptured** (eliminates many trial-plan options)
- Initial data set: May 17, 2002 for flights in Cleveland ARTCC
- Need to generate data sets with increased traffic levels to determine capacity

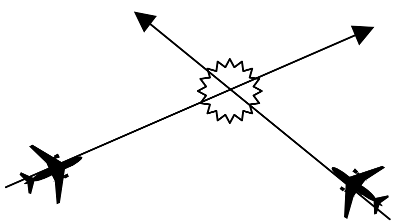
Develop and Evaluate AAC Resolution Algorithm



Multi-Trajectory Conflict Detection

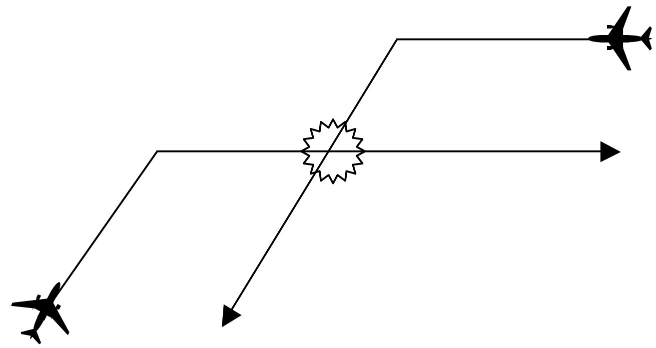
Dead Reckoning (D.R.) vs. D.R.

Detection range: 4 min.



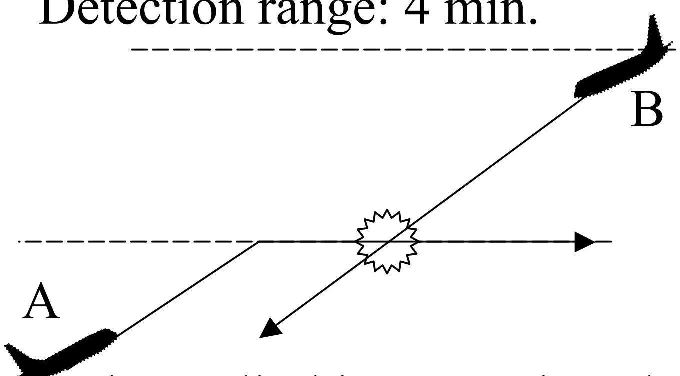
Flight Plan (F. P.) vs. F.P.

Detection range: 20 min.



F.P. vs. D.R.

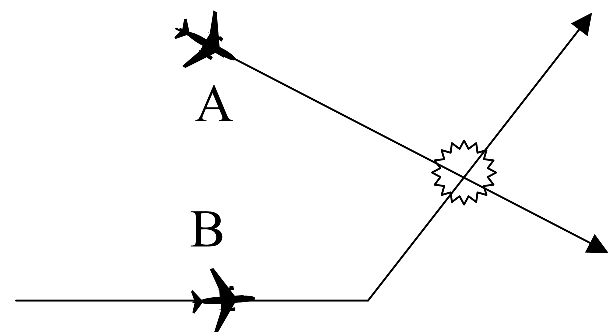
Detection range: 4 min.



A/C A climbing to assigned altitude, descending A/C B failed to level out at assigned altitude

D.R. vs. F.P.

Detection range: 4 min.

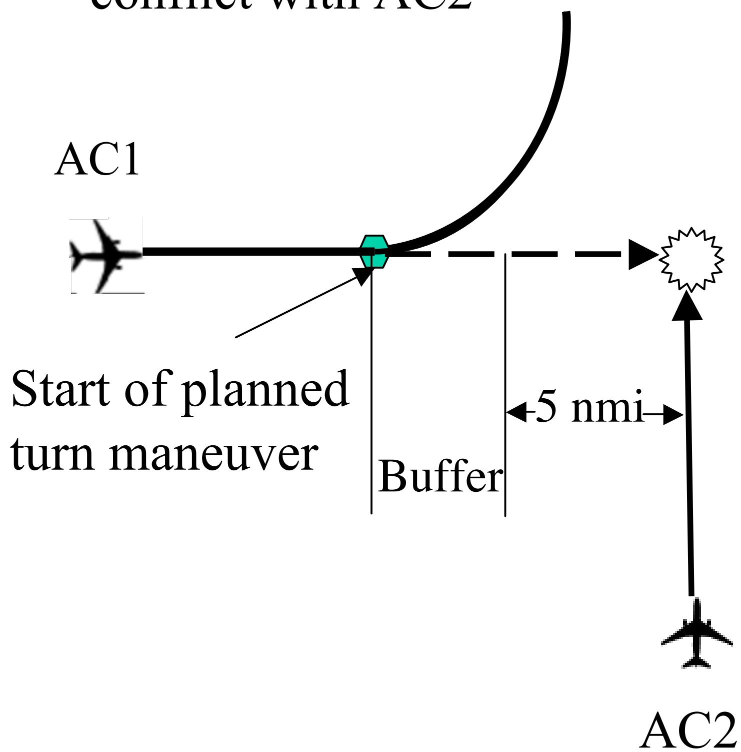


A/C A off F.P. and on a vector, A/C B on F.P.

Critical Clearance Alerts:
A new Type of Alert

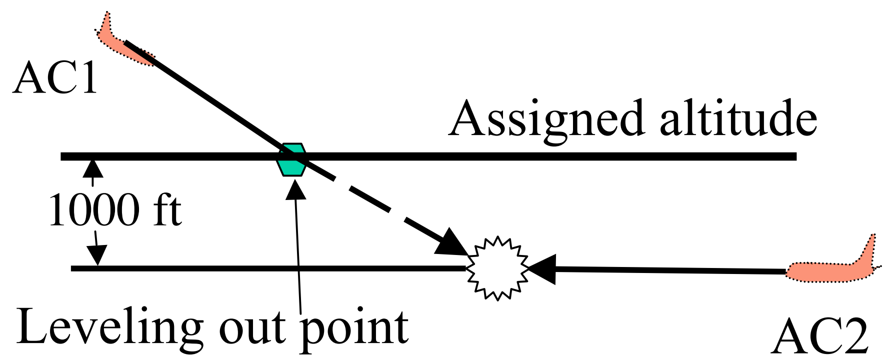
Critical route clearance

Failure of AC1 to start planned turn on time produces immediate conflict with AC2

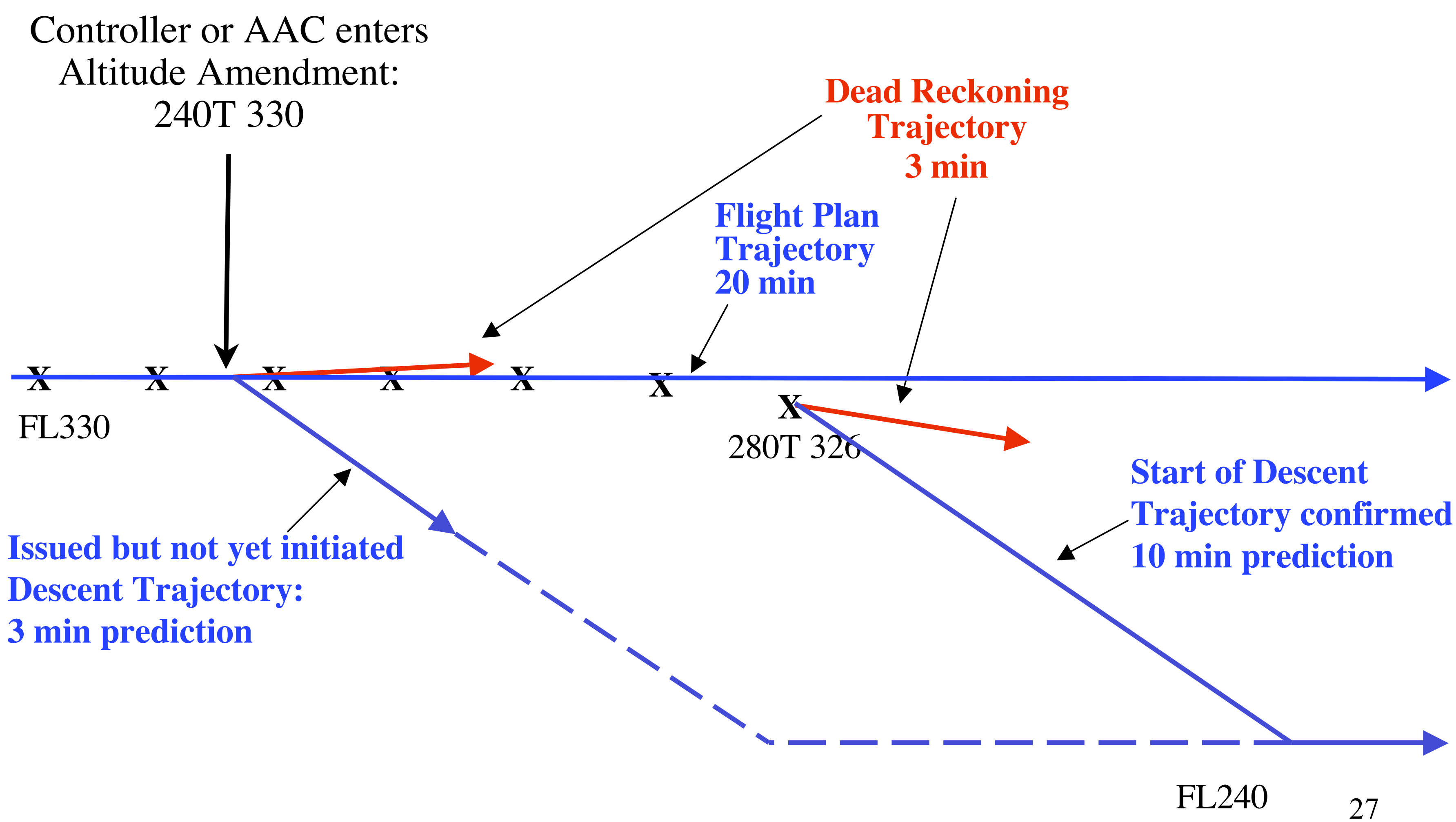


Critical altitude clearance

AC1 descending below assigned altitude produces immediate conflict with AC2



Conflict Detection during Execution of Altitude Amendments



Conflict Detection during Execution of Route Amendments